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THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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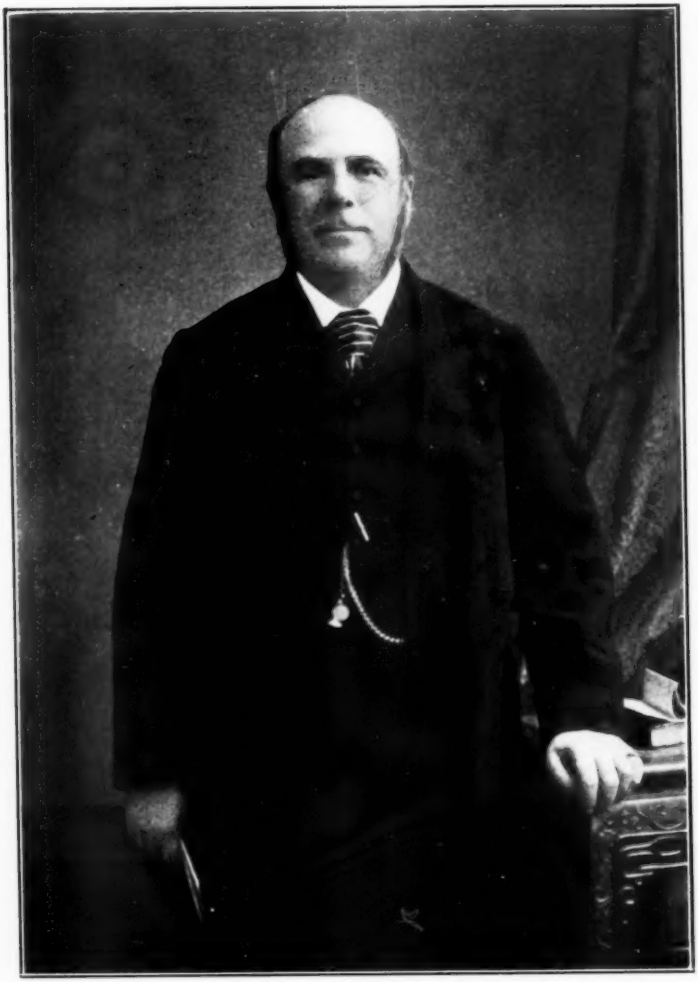
PLATE I.



Robert S Ball

Born July 1, 1840: Died November 25, 1913

Journal of the Royal Astronomical Society of Canada, 1914

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THE BUGLE

BY ALBERT D. WATSON

The Empire needs, in this dark day of slaughter,
Great-hearted men, unawed by doom or dread;
What valor have you shown, what service brought her
To match the tribute of her glorious dead?

You who the loyal standard boldly flaunted
While peace around you guarded like a wall,
What do you now when Freedom is blood-haunted,
Do braggart words but make your deeds seem small?

When in the future days they tell the story
Of how the brave, the hero-hearted died,
When Liberty is crowned with fadeless glory,
Will you be standing honored at her side

Because you ventured all nor sought a reason,
Why other men should die and you go free,
Because you held not back in coward treason
While comrades fought your fight on land and sea?

Amid the gallant ranks that did not waver
Before that blight that shook old Britain's shore,
Will you be one whose prowess helped to save her,
Who went to war that war should be no more?

The troopship in the harbor rideth ready,
The tumult thickens. Hear the scornful word.
The foe is mocking! Lift the anchor—steady.
High tide. The ship's away! Are you aboard?

TORONTO, ONT.,
November 9, 1915.

SIR ROBERT BALL.

THE ASTRONOMER, THE MATHEMATICIAN AND THE MAN

By John A. Paterson

IT does us good to come into contact with leaders in thought and deed. My object to-night is to bring ourselves closer to a great astronomer, and one as good as he was great, to possess more than a hazy knowledge of an original mathematician along some special lines of investigation, a writer of many popular books on astronomy, a delightful lecturer, and, what is rather rare amongst erudite men, a most charming companion, full of humor and story. The "cross-grained muses of the cube and square," as Tennyson puts it, were not with Robert Ball. His muses were pleasant, smiling deities whom everyone loved, although it must be admitted that when he developed his favorite subject, "The Theory of Screws," these muses seemed to sit up straight, and when he added to that title, "A Geometrical Study of the Kinematics, Equilibrium and Small Oscillations of a Rigid Body," the surroundings wore rather a forbidding aspect and became somewhat alarming. As a great professor and observer we revere him, as a popular lecturer, who bent down the branches of the tree of knowledge to the man with the dinner-can, or even to the convicts in Dartmoor Prison, so that the fruit could be touched if not tasted, we admire him, as a writer we delight in him, and as a companion full of pleasant story we love him.

He came of astronomy-blood, blood-royal according to the mystic heraldry of Science. He had an ancestor, William Ball, who was an eminent astronomer, and another, Peter Ball, a deep student of astronomy. His brother, Valentine Ball, C.B., F.R.S., had a distinguished career as a geologist, first in India and then as Professor in Trinity College, and afterwards as

Director of "The Science and Art Museum" of Dublin. His youngest brother was Sir Charles Ball, Bart., F.R.C.S., Regius Professor of Surgery in the University of Dublin. His father was the Honorary Secretary to the Royal Zoological Society of Ireland in 1837. This brilliant son was born on July 1st, 1840, in Dublin, and was brought up amongst artistic and scientific surroundings, both derived from and related to scholars and men of repute, that, as he said, it was "sufficient to make every Ball bounce." He passed his school days at a little village called Tarvin, near Chester, and was noted for his mathematical attainments. In 1857 he entered Trinity College, Dublin; his father had died and his mother found it difficult to give him a start, but with a promise to her that he would work very hard, he commenced his brilliant career, and in 1861 he won the gold medal in Mathematics and in Experimental and Natural Sciences. He reached that, for "he scorned delights and lived laborious days" and nights too. This example is one of many others who climb the toilsome heights of fame. It is a stiff pull, and poverty often gives the spur that wins — "Blessed indeed is the man who has found his work, let him ask no other blessedness." And so this brilliant young Irishman never gave up, but worked to win, and gave his mother, who sacrificed so much for his sake, the holy joy of victory. He had the ancestry, the blood that tells, he had the ability, he had the physical health and strength, and he had the poverty which, as in the case of the great Samuel Johnson, and many others, flogged him to the winning post. Had Homer been the son of a Greek plutocrat, with *drachmas* to spend, would we have had his wonderful epics which have been the admiration and the despair of so many renowned prophets, priests and kings in the literary world? Remember that for this "blind old man of Scio's rocky isle" it was true that

> "Seven cities claim the mighty Homer dead,
> Through which the living Homer begged his bread."

And thus Achilles and Ulysses and the Atridæ became our companions and household words.

He describes how he started in his astronomical career. The first book he read after leaving school was "The Orbs of Heaven" by Professor Mitchel, of the Cincinnati Observatory, who became also a Federal General in the U. S. Civil War. This work opened up to this lad of seventeen new conceptions, and he records, in a very simple way, that then, for the first time, he learned the difference between a star and a planet. Then followed his course at Trinity College when he tackled Newton's "Principia" and Laplace's "Mécanique Céleste." When he graduated, in 1865, he had made up his mind to study for the church; but this was not at all congenial — he might, perhaps, have gone forward and become either a platitudinarian or a latitudinarian or an attitudinarian and either a respectable preacher or a "stickit minister." But at this crisis, when his future career was in the balance, one of those strange providences came to him which so often change the course of a life. Dr. Johnstone Stoney invited him to act as tutor to Lord Rosse's sons at Parsonstown, Ireland. Lord Rosse had been President of the Royal Society and was one of the most prominent men in the Kingdom. His great telescope was then, and, indeed, still is, the largest reflector. After due consideration young Mr. Ball accepted the invitation and changed his design from becoming one kind of a "sky-pilot" to that of another kind, one of a more material and physical description. Being a devout man he made all the better astronomer, for "an undevout astronomer is mad."

Ball now was fairly launched for his life work as a leading astronomer. His work at Birr Castle, the seat of Lord Rosse, was ostensibly that of a teacher to the boys, but the eagle could not be "cabin'd, cribb'd, confined," it must soar. Teaching, mere teaching, without investigation, has been described as "the grave of the intellect," and Ball's active mind could not readily undergo sepulture. He found himself in an atmosphere that trained him for his great life work, for here was the home of the mighty telescope that is to be surpassed only by plans already made for the installation of a yet greater reflector in

British Columbia by the Canadian Government. Between two great walls swung a tube 60 feet long and more than 6 feet in diameter — large enough to be the funnel of a large steamship. At the lower end was the mighty mirror or speculum weighing three tons; the whole output cost $150,000. The instrument was raised by a winch and the observers made their way to the galleries and looked down through the top, or elevated end. Four men assisted the observer. One stood at the winch to raise or lower, another at the lower end of the instrument to give it an eastward or westward motion as directed by the astronomer, while the third had to be ready to move the gallery in and out, in order to keep the observer conveniently placed with regard to the eye-piece. That was before the day of the electrically-rising platform. It was the duty of the fourth to look after the lamps and attend to minor matters. This great mirror has been removed from the telescope and is now placed in the Victoria-and-Albert Museum, South Kensington, London. Ball began this new chapter in his career in 1865. At this time Dr. Johnstone Stoney was the astronomer in charge, and he made his work with the telescope immortal by his observations of the Nebulæ. Ball soon acquired the passion of observing. He records that he would go up to the observatory as soon as it was dark, and he adds that nothing amazed him so much as the extraordinary speed with which the hours passed. "A look at my watch," he says, "might show it half-past eight. When I next drew it out of my pocket at what seemed no great interval of time it would show half-past eleven. On a third occasion I would find it ten minutes to two." Like Herschel, he often observed from dusk to dawn. It was often very cold in that damp winter atmosphere of Ireland. Later in his life when he was at Dunsink he wore a buffalo coat when observing. He used to say that future astronomers would be deprived of such comforts, owing to the extinction of the buffalo, and that notwithstanding the benefits he had derived from the coat, he regretted his small contribution to the obliteration of this noble

animal. We do not realize the difficulties of a genuinely enthusiastic observer. Professor Barnard, in 1899, wrote Ball that he once worked all night in the dome of the Yerkes Observatory at a temperature of 26° below zero, and very often on other occasions below zero. Lord Rosse devoted years to making a drawing of the great Nebula, which was a wonderful piece of work, and being engraved on steel became a standard. But now astronomical photography has swept away the value of the assiduous labors of the former astronomer.

I find a startling record at this period of the great shower of Leonids on 13th November, 1866. For this the telescope was useless. We can see a meteoric shower with the naked eye, or rather, to use the expression of a Boston lady of delicate modesty, with the "undraped optic." Ball records that, "from a height of 60 feet above the ground I saw a spectacle which even after an interval of forty years was the grandest I ever remember having seen. They came in dozens, in scores, in uncounted hundreds and finally in myriads—the scene was unspeakably sublime—not a sound was heard. It was in the dead silence of dark night that the heavens were scored in every direction by these streaks of light." Ball came into contact with Sir Wm. Huggins, K.C.B., the President of the Royal Society, whose investigations into the spectra of nebulæ proved they were largely gaseous in nature, and thus the well known nebular theory was strengthened indeed, if not finally proved.

From 1867 to 1874, the subject of our story became Professor of Applied Mathematics and Mechanism in a new institution founded by the Government, called "The Royal College of Science." In this connection it is recorded that he used in his lectures an apparatus, described by Professor Willis, for the use of lecturers and experimenters in Natural Philosophy. It consisted of a multitude of parts—pulleys, gear wheels, etc.,—not mere toys but actual machines, which by use of a suitable frame work could be built up into various shapes. This episode became more than ordinarily interesting, because I find that on

the 18th of November, 1872, Professor Loudon, of our own University here, wrote to Professor Ball asking for directions or a model of this useful apparatus.

Ball became Astronomer Royal of Ireland in 1874, and held that post until 1892 at the Dunsink Observatory. This office was not supported by the Government but by Trinity College, Dublin. I have not yet spoken particularly of the humorous side of this Astronomer Royal, but I must not delay that pleasure either to you or to myself. The transit of Venus took place in 1882, at 3 p.m., on the 6th of December. At that hour in that latitude near the winter solstice the sun would be nearly setting. On the previous day he went through what he calls "a full dress rehearsal" by pointing the telescope to the sun and following it down to the position it would be in at the time of the transit 24 hours after. He found to his vexation that it would set directly behind a tree which belonged to a dear friend and neighbor, so he sent him a note and asked him whether he intended to allow his tree to stand between the Observatory and the transit of Venus. His friend asked whether he could not arrange for the transit to be pulled off in some other place, but on being assured that even the Astronomer Royal could not arrange that, the obnoxious tree was levelled to the ground. Next day it snowed and at the critical time the sun was invisible, but suddenly the sky lightened, the sun burst forth behind that very place where the tree had stood the day before, and the globe of the planet Venus stood out on the solar disc — the goddess Venus was, so to speak, looking into the face of Apollo. But only for a few minutes; the sky became overcast and the phenomenon that will not be seen by any human eye until June, 2004, ended. The humor of this typical Irish gentleman sometimes led him into trouble. The work of Piazzi Smyth, the Astronomer Royal of Scotland, on the Great Pyramid was under discussion, and Astronomer Ball made a few remarks at the end of a lecture on "Egyptology," delivered by a friend of his, and some allusion had been made to the extra

ordinary conclusions of Piazzi Smyth, and he told a little story of a certain person who satirized the Smyth theory thus: "I think the methods introduced by Professor Piazzi Smyth are of the greatest interest. They may be extended not only to measurements of the Great Pyramid but to other measurements as well. In fact while the learned professor has been addressing you I have myself been making a series of measurements with a pocket rule — I have been measuring the dimensions of my hat. I find that if I divide the diameter of the hat by the precession of the equinoxes, add the logarithm of the depth of the hat to the co-efficient of aberration and take the square root of the whole, I arrive at a number which is the identical age of Mr. Gladstone." This was duly reported in the daily press, which, of course, always reports anything unusual and outré, and the unlucky story-teller lived in daily terror and in a bath of cold perspiration, expecting some gentle remonstrance from the Royal Observatory at Edinburgh heaping coals of fire on his head.

The instrument at Dunsink was called the "South Equatorial," its name not referring in any way to its geographical position, but to the name of its donor, Sir James South, who died in 1867, within a week of Lord Rosse. De Morgan wittily described this gentleman as the "Starlit (k)night." Ball took up energetically the work of attempting to find stars with a large parallax by what he called "reconnoitring observations"; he did not find many stars with a large parallax and it was a valuable addition to astronomical science to know that there were very few stars with a large parallax, or in other words, very few stars within a measurable distance. I find it recorded that he worked at this for years up to two or three o'clock in the morning. Before he went to Dunsink as Astronomer Royal he consulted Professor John Couch Adams, of Neptunian fame, who at that time filled the Lowndean Chair at Cambridge, as to a line of research. Professor Adams advised him to investigate the "Theory of Jupiter's Satellites," that of "Precession and Nutation," also that of "The Satellites of Saturn," and that of the "Librations of the Moon." Any one of these is enough for an

ordinary lifetime but our subject lived the strenuous life. His life was a beautiful life, enlivened with his love for his children and his devotion to his grandchildren, of whom he had six. His simple goodness appealed to their youthful minds, for on one occasion when they were listening to the history of the patriarchs, Robin, aged four and a half, inquired "Was Abraham as good as Grandpa?" He was a most delightful conversationalist and would expatiate in a charming way on the current topics of the day. He could talk most learnedly and interestingly on botany, zoology, geology and engineering; and even political economy he could explain by the hour. He had not the same views that Tennyson had when he sang,

> "What be these two shapes high over the sacred fountain,
> Taller than all the Muses and higher than all the mountain?
> These are Astronomy and Geology, terrible Muses!"

To this Astronomer Royal they were genial companions and loving friends.

The undergraduates of Trinity attended the observatory on four successive Saturdays in the spring, annually, and after a morning's demonstration they were regaled with a lunch fit for the gods. The astronomer understood students and he reached them through head and heart, and also through the physical organs that lie below the heart. In 1883, he had trouble with his right eye. These were not the days of celestial photography, and practical astronomy put a severe strain on the sight. He eventually completely lost the use of this eye, but that hardly diminished the activity of his life work. On the 23rd of January, 1886, the honor of Knighthood was conferred upon him at Dublin Castle, by Lord Carnarvon, then Lord Lieutenant of Ireland. Thus he was endorsed by Her Majesty, the then Queen, as "the man of ablest mind, highest ideal, and noblest pursuits in the kingdom," to use the words of Professor Piazzi Smyth, the Astronomer Royal of Scotland. But that made him no better astronomer, for we have read somewhere that

"A prince can mak' a belted knight,
A marquis, duke, and a' that;
But an honest man's aboon his might,
Guid faith he mauna fa' that!
For a' that and a' that,
Their dignities, and a' that,
The pith o' sense, and pride o' worth,
Are higher rank than a' that."

I have referred to the attractive humor of Sir Robert Ball, for so we must now call him. His wit was such that never hurt, it never with him took the place of knowledge — his humor was the salt of conversation, not the food. Sydney Smith well says "Man could direct his ways by plain reason, and support his life by tasteless food; but God has given us wit and flavor and brightness and laughter to enliven the days of man's pilgrimage and to charm his pained steps over the burning marle." At this stage I give you a few typical illustrations.

It was the practice of the Board of Trinity College to visit the observatory once a year; their proceedings were recorded in the Observatory Book. Sir Robert ventured to relate to the graduates of Trinity College, who were assembled at a dinner in London, the history of two clocks, in these words,—"It was in 1793 that the Board recorded in the minutes their resolution to have two observatory clocks sent to Crosthwaite, an eminent Dublin clockmaker, for repairs. I cannot follow their history in all its details, 'not through each devious path, each changeful year of existence.' I must rather strive to give pictures from time to time of the thoroughness of the way in which Crosthwaite undertook his work, and of the splendid resolution with which the Board of the period dealt with the successive exigencies as they arose. The clocks were sent in 1793. After seven years, in 1800, I find that Crosthwaite was asked whether they were ready. It is quite obvious that the Board of 1800 must have contained some impatient and inconsiderate member who had urged this precipitate action! That it was wholly unreasonable to expect the clocks to be repaired in so short a time as seven years was clearly proved by the fact that even four

years later — in 1804 — we find that they were still in Crosthwaite's hands. In 1806, the clocks not having yet been returned, the Board, in their wisdom, felt that the moment for decisive action had at last arrived. They went so far as to instruct the Bursar to call upon Crosthwaite. This determination, inexorably carried out, was attended with the most gratifying success — so much so that, when the Board met at the Observatory one year later, — in 1807 — the report of the Royal Astronomer conveyed the welcome assurance that he had no doubt whatever that the clocks would be speedily returned. Eight years later — in 1815 — one of the clocks was still in the hands of Crosthwaite, this most careful clockmaker, and so it was in 1816. That, I greatly regret to say, is the last record we have of these interesting time-pieces. Astronomers are, however, accustomed to deal with such vast periods in their calculations that even the the time taken to repair a clock seems but small in comparison."

To those who consulted him on scientific matters not connected with astronomy he would sometimes send a playful reply. A certain Charles Hare Phipps, M.A., (T.C.D.), had invented a "perfect" lifeboat and had submitted all details of his marvel to Sir Robert, who wrote in the most eulogistic terms of the lifeboat as the super-climax of perfection, the non-pareil of naval architecture, unquestionably the most remarkable boat ever produced. Then followed this postscript — "P.S. The only thing, my dear Phipps, to be said against your invention is this — the lifeboat will not float."

Sir Robert was frequently invited to present the prizes at scoools. On such an occasion he wrote thus, "To-night I am to distribute the prizes at a girls' school in the Guild Hall. I am to make a speech on goodness only knows what, but I understand I must refer to Ruskin, the May Queen, the advantages of cookery lessons, female franchise, and the merits of higher grade schools for the daughters of college bed-makers. Then I am to give a lecture on behalf of 'District Nursing' as per enclosed. The theatre is expected to be filled, and phenomenal receipts are anticipated. This, too, in spite of the fact that the faith-healing

party is prominent in Cambridge. They now hold Sunday meetings to cry 'down with priests, doctors, and all other embodiments of superstition and vanity.' P.S.—I am bursting—just bursting (2000 lbs. on the square inch) for a good talk."

He thus expresses his views on a certain professor whose energies as a college tutor were not remarkable: "I believe he finds it almost impossible to do any work between meals."

He once spoke of a scientific meeting, where the question arose as to why the woodcock, which starts in a bee line south in its migration from Norway, should arrive on the west and not on the east coast of Ireland. The explanation suggested by a learned geologist present was that the diurnal rotation of the earth during the bird's passage had brought the west coast under it by the time it had reached Ireland.

He spoke of one of his cousins who in his youth was fond of the wildest pranks and adventures, but was, nevertheless, of a religious turn of mind. When discussing his future career this boy told his parents that the job he felt best qualified to fill was that of chaplain on board a pirate.

At another time it is recorded that there happened to be some discussion as to the duration of the coal suppy, and Sir Robert said, "People say that when the coal fields are exhausted we can use electricity, forgetting that its production depends on the coal supply. You might as well say that if the horse that draws the canal boat drops dead, we could still pull it along with the rope." This, in view of the modern development of the sources of electrical power, seems an extraordinary statement to be made by a leading scientist not very many years ago. It simply proves not only that the visions of one year become the realities of the next year, but also that what is regarded as impossible at one time becomes easily attainable not long thereafter. We have learned, since this statement was made by a man of such repute, that Electra no longer crouches in the gloom of a coal mine, but has her rainbow throne in the crystal glories of the waterfall, and her liquid hand holds the lightning in its grasp.

An aspirant for fame on the lecture platform asked him for some recommendation, and Sir Robert wrote: "You can, of course, refer to me when you are writing, and, if they really apply to me, you will get such a character for a lecturer, that even though you were directly inspired at the supreme moment by the angel Gabriel, you would create bitter disappointment, such would be the expectations that will be raised by what it will be my duty to mention."

Referring to his misfortune in losing his right eye, with unparalleled good humor he writes: "I commenced a new imposture on the public yesterday with a glass eye. The last word of the oculist to me was: 'You will *probably* be much more comfortable than you have been for a long time; you will *certainly* be much safer.' I have as yet really had no trouble, nor do I see any reason to dread it. I had to call on a high official the other day on some business for a friend. He had a wig just like ————'s, and he had a set of false teeth like no other human being. As I contemplated these curiosities with a steadfast gaze of my glass eye, the pious thought rose in my bosom, 'We are fearfully and wonderfully made.'"

I have referred to the great display of Leonids in 1866, and we will all remember that we expected a similar display in 1899. On the night when they were expected, a kind of informal "at home" was given at the Cambridge Observatory, and as it was to be an all night séance, refreshments were provided. The affair was, as we remember, not a success; the astronomical wheel in Dame Nature's huge machine slipped a cog, so to speak. Sir Robert sends a cheque to pay for the supper, and adds: "But lest there should be any doubt as to my future wishes, I now hereby authorize you to order a sumptuous supper for all and sundry who will attend at the observatory on the occasion of the next meteor shower in the year A.D. 1933. I will pay the bills, no matter what they are. I will only leave you the trouble of discovering my address."

Writing to a friend on November 23rd he said: "The meteors seem to have been a fiasco. The only person who saw

them was a policeman, but that was on the wrong night. I am assured that Constable B. 9999, on whose testimony the phenomenon is recorded, is a teetotaler. The only points that I have been able to collect with certainty are, that he was sitting on a gate at the time, and that he saw hundreds of stars; otherwise the account is a little obscure."

But I forebear to add many other *jeux d'esprit* which are ready to hand, for fear this lecture may degenerate into a mere funny column. These which I have selected lend emphasis to that very old epigram that "a little nonsense now and then is relished by the wisest men," and in quoting that, I am referring not only to Sir Robert Ball, but to others who are nearer to me in their places and better known to me in their persons. Courtesy compels me to add, "by the wisest women too," although, indeed, it spoils the rythm and the metre — but what of that?

Sir Robert's lectures at Cambridge were not limited to geometry; with rare ability he expounded the deep theorems of pure mathematics by Laplace and Lagrange, the great French astronomers. There are other alliances than those of war — alliances in the pure and lofty empyrean of science, where dwelleth Urania, the Muse of Astronomy. But our subject was not a scholarly recluse; he had a public spirit. For he ventured to mix in politics, which I will detail hereafter.

In January, 1894, he had some unusual visitors at the Observatory. The great actor, Sir George Alexander, was about to produce the "Masqueraders" at the St. James Theatre, London. The cast included an astronomer, and part of the scene was laid at an observatory; so the playwright, Henry A. Jones, and the actor visited the astronomer, and saw the inside of a real observatory, that *sanctissimum sanctissimorum* to the outside world.

He speaks of the discovery of radium, and, in 1903, says that it gets over the greatest of scientific difficulties, *viz.*, the question of sun heat, for the sun's heat could not have lasted more than 20,000,000 years, if it is due to contraction, whereas the geolo-

gists need 200,000,000 years for their theories — and now radium bridges the difficulty. As to the relative ages of the planets, he confesses he knows nothing, and adds with his usual quip: "I only say to the other planets what the Irish carman said to the old lady 'Whatever your age is ma'm, you don't look it.'"

At a certain convivial gathering at a nobleman's house, where many eminent men were entertained, Mr. Justice Ross, like Boffin of Dickens fame, "dropped into poetry," and united in these verses the great astronomer and his equally famous surgeon brother, Sir Charles Ball:

"The Prior sent his message,
And in answer to his call
There came the great twin brethren,
Who bear the name of Ball.
One holds aloft the famous lance,
That lays *appendix* low,
The other is on friendly terms
With all the stars that glow.

With that splendid chivalry that distinguishes every true man of science, for such a one rises far above the jealousies and rivalries of professional renown, he says, in 1907, when Lord Kelvin died: "Know ye not that there is a prince and a great man fallen this day in Israel? No death since the death of Darwin has impoverished the world as has the death of Lord Kelvin. He was a good man, as well as a transcendently great man. No more nobly spent eighty-three years ever were lived by mortal. Oliver Lodge said that he held it a high privilege to have lived in the same generation as Kelvin. This tremendous event has thrust all other things from my memory." And this great Lord Kelvin was once plain "Wully Thamson."

Sir Robert was a distinguished lecturer. It was Faraday who first suggested that he give the "Christmas Lectures" at the Royal Institution; he himself had given a famous course on the "Chemistry of a Candle." This Royal Astronomer and Lowndean Professor of Mathematics was so great that he lectured to children. He began thus: "This lecture is addressed to

children. I observe that a great number of elderly relatives, and a large number of adults who have no children to look after them are also present. Well, children, you and I will not mind all these grown-ups if they will only behave themselves properly." After that the children sat up and listened unweariedly. There were present Sir Squire and Lady Bancroft, Madame Albani, the President of the British Association, and the Lord Chancellor of England. These "Christmas Lectures" were afterwards published under the name of "Starland."

Sir Robert was also one of the lecturers under the Gilchrist Trust. Its history is rather remarkable. A debtor of Gilchrist owed him at one time the trifling sum of £17:10; not being able to pay it he offered Gilchrist in lieu, some property in Australia, fronting on Sydney Harbor. This lot ultimately sold for £70,000, and the Trust had an income of between three and four thousand pounds a year. At these lectures there were 800 tickets sold for one penny each, and the hall was jammed long before the lecture began. He was asked, "Do you not get weary lecturing night after night?" His reply was "Ask the good golfer if he gets weary hole after hole. When you have some skill in your art the exercise of it is delightful." "Blessed be the man that likes his job, let him ask no other blessedness," say I.

I delight to record the following: The Sunday Lecture Society in 1899 invited him to lecture to 3,500 people; this Society informed Sir Robert that they defied the British Lord's Day Alliance, they charged no entrance fee, and asked him to name his fee — Sir Robert declined to be tempted. He had a large repertoire and on one occasion wrote to a lecture committee who asked his subject: "I can congeal you with the 'Ice Age,' or burst you up with the 'Thunders of Krakatoa' — I can tell you awful whoppers about 'Time and Tide,' or petrify you with a burst of eloquence about 'Invisible Stars' — I usually put the greatest rot into a lecture called "Other Worlds.' There is a faint, very faint *soupçon* of theology in 'An Evening with the Telescope.'"

In one of his lectures, to illustrate the unfathomable immensity of the Universe, he quoted these lines :

"But number every grain of sand,
Wherever salt wave touches land,
Number in single drops the sea,
Number the leaves on every tree,
Number earth's living creatures all,
That run, that fly, that swim, that crawl ;
Of sand, drops, leaves and lives the count
Add up into one vast amount,
And then for every separate one
Of all those, let a flaming sun
Whirl in the boundless skies, with each
Its massy planets, to outreach
All sight, all thought ; for all we see
Encampassed with infinity
Is but an island."

A scientist like Sir Robert was the object of some very strange correspondence. He once told his audience that he had received a letter from a grocer who desired to become an apprentice at Dunsink ; he admitted he had lost the latter, but offered to reproduce it from memory and I fear that the reproduction was somewhat exaggerated. Thus it ran :

Most Honorable Sir,

"I am a grocer's assistant, but my spirit is above the selling of sugsr and tea and longs for communication with the skies. Could you take me as an apprentice in your observatory? I pass many a sleepless night yearning for the sympathy of the planets. As I weigh out two pennyworth of figs in the balance I think of Libra, the constellation, and long to soar aloft with the celestials. The pair of children that have just come into the shop make me wish myself to be the Heavenly Twins, and when they ask for Bull's eyes I thought of the constellation of Taurus and the bull's eye that twinkles above. In fact, dear sir and most honored individual, my mind finds no rest for the sole of her foot save on one of the heavenly bodies."

Sir Robert Ball had, as, indeed, he was entitled to have, a

full appreciation of the pecuniary value of his platform work, but he sometimes lectured without fee. In the spring of 1907 he was holidaying in Devonshire and was by the chaplain of Dartmoor Prison asked to spare them an hour for one of his "charming discourses." He accepted, and the Governor wrote to say that "the attendance would be upwards of 900, among whom, besides the ordinary laborer, are many intelligent and well-educated men — lawyers, a parson or two, forgers, swindlers and professional burglars." It was impossible to use a lantern, as it would be unsafe to have so many convicts in a darkened room. Having some suspicion of the social condition of his audience, it was difficult to begin in the customary manner, so he omitted the word "Gentlemen," but went right ahead. He told them of the appearance of a new star, how brilliant it was, and how deeply he was impressed with its glory, and so determined to point it out to people as he met them. Amongst other people he encountered was a policeman, and he thus proceeds in his own words: "Having given the officer a short history of the star I adjured him to mark it well as he might never see such a thing again. The constable replied 'All right, Sir Robert, I'll keep my heye hon 'im.'" The audience shook the building with an outburst of applause and the lecture was a huge success. One of his audience afterewards wrote to him to say how much they all enjoyed his lecture, and how one of his virtuous brethren had said to the writer: "Blime me, but when the high swell shot off his mug and told us of that twinkler, and how the bobby said he would keep his heye hon it, it was too funny to hold tight, and we just let her go and larfed and blarst the keepers." There was a certain familiarity of phraseology that caught his strange audience.

In 1882, Sir Robert was appointed Scientific Adviser to the Irish Lights Board in succession to the late Professor Tyndall, who had held the position for a number of years. It became his duty to advise as to the relative merits of the light from gas, electricity or oil to pierce the fogs that enfold the Irish coast.

He dealt with fog signals and light-houses and light ships, and all that appertained to the safety of vessels.

Upon at least one occasion Sir Robert showed some poetic skill, and his Muse, stirred by a knowledge of botany, celebrated in verse the plant called "Elecampane," which grows amongst the ruins of an ancient monastery in Kerry County.

Throughout his whole career he continued a close attachment to his Alma Mater, Trinity College; the graduates and classes honored him exceedingly, and he in turn honored them. When the Annual Dinner came round the question was "Is Bali coming — is he going to speak!" If he was, the tickets were readily taken. Trinity College, Dublin, was the first of the old Universities to "remove the barriers" and grant degrees to women, but Ball said "the removal of the barriers does not immediately produce the desired result. At the Zoo the old bars of the lion's cage, which would have kept in a locomotive, were replaced by lighter ones. The public were quite satisfied; but the lions were found cowering in the corner with timidity. They thought the bars were to keep the public from attacking them."

Sir Robert made a visit to Vadso, Norway, in August, 1896, as a member of the Solar Eclipse Expedition arranged by the Royal Society and the Royal Astronomical Society. Dr. Common, the President of the latter, was the responsible head of the expedition. This was the first time in which the coelostat was used to observe an eclipse. This is a plane mirror made of the finest material to give the maximum amount of reflection. It is made to rotate about an axis in its plane and parallel to the earth's axis. If the mirror be made to rotate by clockwork, so that its rate is exactly half the rate at which the earth rotates on its axis, the light from the sun is always reflected in the same direction, notwithstanding the motion of the sun. The mirror in this case was sixteen inches in diameter. The telescopes were duly mounted on solid supports — a staff of seventy persons was regularly organized and drilled to observe carefully the various phenomena, so as to utilize to the utmost the limited period of

106 seconds during which the totality lasted. But every prospect was pleasing and the weather alone was vile. The clouds for a large part of the time covered the solar disc, and in theatrical parlance it was a "dark house," darkened by the clouds and not alone by the lunar disc as properly happens at every well-regulated and well-behaved solar eclipse. Some very meagre results were obtained, but of the phenomena characteristic of a total eclipse — the corona and the prominences — not a trace was to be seen. Apollo, with great gallantry that day draped himself in clouds, being unwilling to let these inquisitive men at Vadso, see Diana in his arms. A solar eclipse certainly furnishes a very concentrated form of scientific interest — just $1^m\ 46^s{\cdot}4$ of totality — at Vadso that day. Nature keeps her secrets well, though astronomers have with untiring vigilance attempted to open her treasure-house and learn the nature of the sun's constitution and genesis. The investigation of the corona and those wonderful hydrogen flames only seen at a solar eclipse under favorable surroundings will yet unravel the mystery. "'Tis better to have tried and lost, than never to have tried at all."

It would be unpardonable in me to forget that Sir Robert visited Canada, in 1884, when the British Association met at Montreal, and he tells us too of his visit to Niagara Falls. He does not mention that Toronto was then in his itinerary, but it soothes our anguished feelings to know that he did not visit Hamilton. He also visited the United States in 1887 and 1901, and he speaks in glowing terms of Simon Newcomb as one of the greatest mathematicians in the world. He discovered, too, the jibes about Boston culture, quotes a New York paper in its items of news saying "the sun is 95,000,000 miles from Boston," and that a Boston man, after hearing Macbeth, said he didn't think there were five men in Boston who could have written Shakespeare. He was the chief lion in the astronomical cage, and he writes delightfully of the other lions and lion's whelps he met, who were either couchant or rampant in the Colleges and Observatories. He meets and describes men all the way from Brashear, the instrument maker, to Carnegie, the millionaire. This man

was many sided, and among the sides golf occupied its own place,—an honorable and genial player. When his antagonist missed a putt of six inches he never laughed, although good men have done such things, but on such melancholy occasions he preserved a stony silence.

A few words as to Sir Robert and politics are not misplaced. He was a strong Unionist, but his scientific attainments and personality had won the respect of every Irishman of every class and shade of political opinion. When the second Home Rule Bill was under discussion he was at an entertainment in Dublin where many eminent men were assembled, and a certain cleric kindly informed him in public that whatever changes might be made in Ireland, men of his standing would not be interfered with. "I am delighted to hear it" was his reply, "I had grave apprehension lest a Nationalist Government might begin to tamper with the constellations. I feared I should live to see the day when I should look on "great O'Brien (not Orion) sloping slowly to the west."

He attended a political meeting for the first time on the 15th February, 1893, in order to hear the Hon. Ed. Blake, formerly Prime Minister of Canada and then an Irish Nationalist member. He was urged to become a candidate to represent Trinity College but he declined. However, he addressed public meetings, but with indifferent success; he was monarch on the lecture platform, but the heckling of the sturdy and independent elector was not congenial. On one occasion he was almost knocked off his feet by a sturdy glassblower at the back end of the hall yelling out, "I say, Professor, you've got your blooming heye at the wrong hend uf the telerscope."

As this address has been cast into a popular mould, there is danger in our losing sight too much of the splendid service Sir Robert performed for the advancement of science. He wrote treatises pertaining to the domain of pure mathematics, and notably on the "Theory of Screws." From 1876 to 1900 he published many memoirs upon this recondite subject; and in 1900 these were combined into an imperial octavo

volume of 544 pages; this was his "magnum opus," and it racked the brains of all the leading mathematicians. Sir Robert, however, could not content himself with that, and he delighted Section A of the British Association, at its Manchester Meeting, in 1887, with what he called a "Dynamical Parable," which was a popular explanation of his theory. This drew from an Aberdeen Professor these words: "Not since the time of Galileo has any attempt been made to combine wit and wisdom in this manner, and not every one would venture on the experiment with much hope of success." A treatise on "Spherical Astronomy" was the last of his mathematical works. This appeared in 1908, and struck his friends with wonder that a writer who revelled in the flowers of sparkling fancy which embellished his many books on descriptive astronomy, and who had even successfully injected a pleasant flavor into the "Screws," should have produced so "unromantic and unemotional a treatise, filled with tedious routines of astronomical reductions." This simply proved the high range of the man's power and gifts. But we are reminded that literature has produced other parallels, for did not Lewis Carroll write "Alice's Adventures in Wonderland" and "Through the Looking Glass"? And who has not laughed at the bright little girl who followed an extraordinary rabbit into a rabbit-hole, who does not drown in her own tears, but entertains us with conversations with the crusty old Duchess, a mad Hatter, a sleepy Dormouse and a March Hare, and plays croquet with the Queen of Hearts! And we know that this same Lewis Carroll was none other than Charles L. Dodgson, a most accomplished mathematician, who wrote treatises on "Determinants" and Modern Geometry that would stiffen a brass door-knocker. His books and treatises on mathematics for the scholar were manifold. Professor Whittaker, who succeeded him as Astronomer Royal of Ireland, bears this testimony: "On a consideration of his mathematical researches alone, with which this note is primarily concerned, there can be no doubt that Ball will be regarded by

posterity as one of the two or three greatest British Mathematicians of his generation."

He is best known by his books for the man at leisure, for the lady in her boudoir, and even the man or boy on the street. Here are some of them, "Elements of Astronomy," "The Story of the Heavens," "Time and Tide," "The Cause of an Ice Age," "Starland," "In the High Heavens," "The Story of the Sun," "Great Astronomers," "The Earth's Beginning," "A Popular Guide to the Heavens," "In Starry Realms." When we consider these we do not wonder that his life motto was a passage from Carlyle noted in his papers by his son, W. Valentine Ball, as far back as 1879:

> "Happy is the man who has found his work; let him ask no other blessedness. He has a work, a life purpose; he has found it and will follow it."

In all that I have written I am deeply indebted to the most interesting "Reminiscences and Letters," edited by his son and published a few months ago.

It grew late and dark with this genial savant on the 25th of November, 1913, at the ripe age of seventy-three, and it was then that the black camel knelt at his gate. At the funeral service his favorite hymn, "Rock of Ages," was sung. He was buried at Cambridge, near the grave of Adams, the discoverer of Neptune. His scientific work thus ended, but it will live, and will form a great pillar in that mighty temple of human wisdom which the ages are slowly building with many a strong tower and stately column and graceful minaret, upwards, ever upwards, for the benefit of mankind and to the glory of God.

TORONTO.

A CENSUS OF THE SKY*

By R. A. Sampson

IT might seem to call for some remark, even some apology, that at a period like the present one, when all the ordinary interests of life disappear or are transformed, that we should meet as we had arranged to meet, and exchange with one another the indifferent truisms of Science.

There occurs to me a passage in a book by a celebrated private in the French Army, Anatole France's "Isle of Penguins"; one of his characters, deeply depressed by the perversity of the world, reflects somewhat as follows: "Since riches and civilization bring as many occasions for war as barbarism and poverty, since the folly and ill-will of mankind are incurable, there remains one good deed to do: some wise man shall collect enough dynamite to blow this planet up. Then when it whirls in fragments across space some imperceptible alleviation will be felt in the universe, and some satisfaction will be given to the universal conscience — which, indeed, does not exist."

While we feel as much as any this same savage indignation — Swift's *sæva indignatio* — that folly and ill-will have still the power to throw the whole world off its bearings, and while we are all of us busily engaged in collecting enough dynamite to blow some parts of it to pieces, it is wise to remind ourselves that there are other things besides folly and ill-will that are indestructible, and among these is the desire to increase natural knowledge. We are at no loss for precedents. Our Royal Society was initiated in the midst of civil war. The "Principia" was published a year before the Great Revolution. Kepler

*Being an Evening Discourse delivered before the British Association by Professor R. A. Sampson, M.A., F.R.S., Astronomer Royal for Scotland, on September 11, 1915.

found in the Thirty Years' War no reason to interrupt his study of the planetary motions, nor did Gauss in the invasion of Napoleon. Successive volumes of *Mécanique Céleste* came out, and bear evidence in their titlepages of the political changes of the French Revolution. Hevelius and Gassendi corresponded across a Europe in turmoil, and Newcomb worked with Delaunay at the theory of the moon while the Paris Commune raged almost to the doors of the Observatory. Had Science always waited to advance till times were quiet, it would have remained to this day uncommonly near to its starting-point.

The subject to which I ask your attention for an hour to-night is not a small one. It is nothing less than the simplest comprehensive view of the whole Universe. Indeed, it is a subject so vast that some have felt that in the study of it human interests would shrivel away, and that as we looked steadily upon its extension we should be gripped with a kind of nightmare, and feel ourselves shrinking and shrinking, and, unless by violent effort we could throw it off, we should seem in risk of vanishing altogether. But somehow that is not the case. Those who most study the matter and those who have lately contributed most to our knowledge are men well known to us, very human beings. Certainly, a correct conception of the Universe must govern the scale of ultimate values of all we do; but in the history of ideas it is remarkable that interest in it has for the most part of the time been satisfied with obvious fairy tales, has, in fact, been limited to the very narrow outlook of what we might immediately expect to accomplish, and has often combined in individuals an intense interest in the question, with a total disregard of any but the individual's point of view — as if even the "vasty halls" of cosmogony were an arena of sport where the attempt was not so much to reach the goal as to gain a place for self-expression. As President for the time being of the Royal Astronomical Society, I keep a certain amount of involuntary touch with such people. "I should like to know, Sir," one of these wrote to me severely the other day, "what

steps are being taken to spread the true chronology and the truth about the Deluge."

Well, perhaps that gentleman was a paradoxer; but it is interesting to bestow a side glance upon the way astronomy has been viewed by acute and catholic minds before the era when the commonplaces of diffused education had blunted a good many first-hand judgments. I shall not take you on a long excursion into history. Two or three pregnant examples will suffice.

Take Bacon's "New Atlantis." In that remarkable country, which had flying men and submarines and scientific stock-breeding for the production of definite variations, it is true that they had a statue to "The Inventor of Observations of Astronomy"; but the systematic contemplation of the heavens does not appear to have formed a part of their national scheme of study:—

> We have high towers, the highest about half a mile in height; and some of them likewise set upon high mountains, so that the vantage of the hill with the tower is in the highest of them three miles at least. . . . . We use these towers, according to their several heights and situations, for insolation, refrigeration, conservation, and for the view of divers meteors; as winds, rain, snow, hail, and some of the fiery meteors also. And upon them in some places are dwellings of hermits whom we visit sometimes and instruct what to observe.

This passage is very disappointing to an astronomer. These hermits, with their magnificent equipment, state support, and Boards of Visitors were nothing more than meteorologists.

Or, again, take Shakespeare. It is admittedly difficult to make out what views, if any, Shakespeare held on any subject, and I shall have to quote words put into the mouth of the light-minded Biron in order to make my point; but we know that the farcial figures of his plays are chiefly pedants and policemen; in particular, the pedant moved him to a school-boy ribaldry, and from two or three references I surmise that astronomy, as a science and apart from its poetic incrustations, struck him as yet another field for the preciosities of his ineffable pedants. "Study," says Biron,

Study is like the heaven's glorious sun,
That will not be deep-searched with saucy looks;
Small have continual plodders ever won,
Save base authority from others' books.
Those earthly godfathers of heaven's lights,
That give a name to every fixed star,
Have no more profit of their shining nights
Than those that walk and wot not what they are.
Too much to know is to know naught but fame;
And every godfather can give a name.

That is all there is in it—giving names; science is nominalism. We may brush it aside; but, after all, it is a painfully shrewd hit against science.

Now there was a very considerable and extended Astronomy in Shakespeare's and Bacon's days. Copernicus's work "De Revolutionibus" was 50 years old. It was, perhaps, not much read; but for a century before devious voyages, lasting for months or years, to North and South America, to South Africa, and to India, had made indispensable a working knowledge and command of its practice, and with the practice grew up a scientific interest.

In 1578, Mr. John Winter passed through the Straits of Magellan "in a good and newe shippe called the 'Elizabeth,' of 80 tonnes in burthen," as one of Sir Francis Drake's consorts. Neither the place nor the vessel can have been favorable to scientific abstraction, yet he determined his longitude there from an eclipse of the Moon. The passage ("Hakluyt," Vol. VIII.) is a gem of accurate astronomy, and I shall read it to you, for every point mentioned is relevant and the conclusion quite justified and near the truth:—

The 15 of September the moone was there eclipsed, and began to be darkened presently after the setting of the sunne, about sixe of the clocke at night, being then Equinoctial vernal in that country. The said eclipse happened the 16 day in the morning before one of the clocke in England, which is about sixe houres difference, agreeing to one quarter of the World from the Meridian of England, towards the West.

Now take a long step from the sixteenth to the nineteenth

century. Passing by a fastidious and academic writer like Tennyson, we find a mind as careless of fact and untrammelled by convention as Mark Twain deriving perpetual delight from the mere scope and scale of things astronomical, in its revelation of the very size of the world as measured in millions upon millions of any units we can tell off. It may be hard to say exactly what this proves, but we may allow it to suffuse the continual plodder with a gentle glow of satisfaction; for without his continual plodding it would never have come to pass.

Undoubtedly the last word of Astronomy must be heard before we can solve the problem of the philosophers upon its material side and place Man in true relation to the Universe.

I suppose it is Evolution that has made us feel responsible for the Universe, incurring thereby, it must be confessed, a very heavy responsibility with fate — a debt that would cause serious anxiety, had not philosophy long since become reconciled to permanent bankruptcy. I mean that, before evolution became one of our fixed ideas, "man's place in nature" was an expression to which only an arbitrary meaning could be attached. There was no obligation to connect the phenomena of the Universe in one long chain. Nothing is more illuminating as to our change of view than to read the words of one of the lesser lights of the eighteenth century — for example, Thomas Wright, of Durham, is an author who is often mentioned alongside Immanuel Kant as having foresight of the Nebular Hypothesis, the great evolutionary scheme of Astronomy. Without depreciating the insight and the breadth of Wright's views on extended stellar systems, the defect — the perfect defect of any evolutionary glimpse in them — strikes one now as an almost painful incompetence. We are sensible of the necessity of connecting all the parts of our system. That is the general interest in a survey of the sky, outside of professional interest in a difficulty overcome and of curiosity — which, indeed, is soon bored by mere magnitude, — and that is the reason why we come back to it again and again, especially now that we are beginning from

more than one avenue to approach some reliable, and one hopes some permanent, point of view.

That avenue which I would ask you to follow this evening is the most direct, the least artificial, and one would say the driest of all — mere enumeration, a census of the sky. But it is not dull. As I shall show you in a few minutes, the material dealt with is of compelling beauty, and, as scientific people, I hope it may interest you to have in brief review the considerable difficulties, instrumental and of organization; the many collateral questions that must be answered before any confident, or even approximate, reply can be given to the main question of how many stars there are, and how they are distributed. And, finally, as British people, I think you feel a legitimate pride to know that this great and unobtrusive work, of central interest to astronomy, that I wish specially to describe to you is all British (including therein the Transvaal Colony) in design and execution: the plans made, cost provided, and very many of the photographs taken by an amateur, the late Mr. Franklin-Adams, a business man of London; the instrument designed by Mr. Dennis Taylor, and constructed by him at Cooke's works at York; the series of photographs completed at the Union Observatory at Johannesburg; and the counts performed and discussion made at Greenwich Observatory by Mr. Chapman and Mr. Melotte, two members of the staff.

[Specimens of the Franklin-Adams Chart were then shown].

You now see, more or less, the problem before you. To "give a name to every fixed star" is a task that we are not likely to undertake. The Arabs gave many of them proper names, which no doubt had some meaning, more or less substantial, but, now passed on to the Westerns with meaning, pronunciation and accent alike in corruption, uncertainty, and disrepair, form a somewhat trying detail to the conscientious astronomer. Ptolemy adopted in his list a crude and picturesque description with reference to the asterism. Thus in Leo, "The one on his muzzle," "the one in his throat," "the one at the tip of his front right claw," "the western one of the three on

his belly," "the one at his heart named *Regulus*." It is a troublesome plan, even for the 1000 stars of which he gives the places. Tycho, who was only incidentally a stellar observer, using the stars to fix his planets, carried on the method of Ptolemy. Not till the beginning of the seventeenth century did Bayer, in his *Uranometria*, introduce the device of attaching the Greek letters to stars in each asterism. The advent of the telescope, with Hevelius and our own Flamsteed, utterly outran any method except that of numbering. Lalande's *Histoire Céleste* in 1801, contained 50,000; Argelander's *Durchmusterung* in 1847, upwards of 300,000 in zones from the Pole to Dec. $-10°$. At each effort the object, if completeness was its aim, showed more mountain-like. In 1879, at the instance of the *Astronomische Gesellschaft*, Argelander's zones were revised by the co-operation of many observatories in upwards of 20 years. It hardly requires proof that with such resources as astronomy has ever commanded, or is likely to command, a complete enumeration upon these lines will never be attained.

If we are to attain a conspectus of the whole, now or ever, we must make a radical reduction in the demands of our problem. Now in all these catalogues the places of the stars are recorded in their two co-ordinates, and the calculations made in each individual case which are necessary to allow for precessional change in the axes of reference. We cannot dispense with knowing where the stars are, but, if our interest is in their numbers and regional distribution, we can dispense with recording it precisely. And if we can take an elevated standpoint, and eliminate the earth, like the Blessed Damozel leaning on the gold bar of Heaven, and see far below

> this Earth
> Spin like a fretful midge,—

why then we may dispense with the troublesome calculation of precession. There is almost nothing left then except to count.

But let nobody think lightly of the importance or the difficulty of mere counting. When the White Queen put to Alice the question

How many are one and one and one and one and one and one and one and one and one and one?

Alice does not appear to have been able to answer. Counting correctly is very difficult, because, so to put it, it requires from the mind a simultaneous hold upon past, present and future. Counting, on the other hand, done carefully, is the only region of knowledge, even of mathematics, in which we can be perfectly sure we are not talking nonsense. Much that was formerly classed as geometry is now classed as nonsense. A circle *has* no properties until we say how it is generated, and we cannot say how it is generated until we make up our minds about continuity, and continuity, to make it intelligible, is now explained in terms of discontinuity — that is, of counting. By counting, infinity is made comprehensible, like an infinite perspective collected upon the narrow space of the retina, as a sequence of converging increments — countless in their number, but countable in their sum or effect.

Counting by samples is another name for the theory of statistics, of averages, with the ramifications of probability, without which matters so disparate as life insurance and the kinetic theory of gases would be equally unmanageable.

I need not labor my point. In counting the stars you have to count a sum of which you cannot tell in advance whether it will prove infinite or finite; you have to count by samples; you have to count by receding steps or grades as far as you can, and then infer the continuation; and, if these grades are incorrectly or debatably demarcated from one another, your results are liable to such enormous uncertainties that they can hardly be held to add anything to knowledge. To have performed this counting, as I believe it has been effectively and securely performed, is, in my judgment, a very great feat, one that would appropriately be taken as a land-mark in the history of the mind; and I do not think I detract from this at all, if I say that those who have actually done the work would not lay claim to more than to have well and truly performed a straightforward task by

established methods. None the less, it marks a stage, a fact among many surmises, an achievement among many attempts.

Counting the stars is nothing else than the method of Herschel's star-gauges, supplemented by a due consideration of all the difficulties which he overstept by intrepid assumptions. When Herschel set up his 20-foot reflector of 18-inch aperture, it was mounted vertically in the meridian with a sweep of a little more than $2\frac{1}{2}°$, and he surveyed the sky in zones of declination, taking everything that came by, and, in particular, counting the density of the fields. These counts were the bases of his papers on the "Construction of the Heavens," which showed that the sun was roughly in the centre of an irregular disc-shaped universe of stars, researches that I have heard Sir David Gill describe as "almost inspired." But, if he was inspired, like other prophetic writers we have to repose upon his genius, for criticism spoils him. It will not do now to tell us that a seventh-magnitude star may be generally taken as seven times as distant as a first-magnitude star. In the first place, calculation is astray, 25 times would be more defensible; but, in the second, though we know that distance must raise magnitude, generally speaking, we are quite unable to verify the connection. But, most of all, though Herschel "looked further into heaven than any man before him," for this purpose he did not look nearly far enough. His statement that in a field of 15′ diameter he counted some 70 or 80 stars, with occasional fields very much denser, would indicate that he reached to the 13th or 14th magnitude. The 15th magnitude more than doubles the 14th, the 16th nearly doubles the 15th, the 17th nearly doubles the 16th. How does the progression continue? Does it go on for ever? Does it go on even as far as we can see?

No real advance upon Herschel's gauges could be made without photography — both because the record is permanent, and so leaves you time to count, and also because the faintness of the stars that you can reach is almost unlimited.

Let me now leave generalities and give you, as succinctly as possible, some details of the work I am describing.

The instrument consisted of a 10-inch lens of 45-inch focus, with a 6-inch lens of 27-inch focus, mounted, together with guiding telescopes, upon an equatorial mounting of the English pattern.

With the 10-inch lens, 17° × 17° upon the sky are depicted upon a plate 15 inches square, and to cover the whole sky upon this scale 206 plates were requisite. The exposure of each plate was 2 hours or 2 hours 20 minutes, so as to reach the faint stars. Northern plates were taken at Mervel Hill near London, the Southern at the Cape, and afterwards retaken at Johannesburg

There are certain defects in every lens which are practically incurable when a wide-angle field is desired — namely, curvature of the field, and astigmatism or replacement of a point-image by two line-condensations at different distances from the lens. It is the art of the lens maker, and of the lens user, to split the residual errors in the least harmful manner.

I show two slides taken from the same plate. The first shows the centre, with images perfectly round, small, and defined. The second shows the corner. You see the elongations in two perpendicular directions succeeding one another, separated by forms that suggest flights of beetles. That these forms are so little pronounced at some 10° from the centre is the proof of the excellence of lens, focussing, and guiding. It is the practice to suppress them somewhat by sacrificing almost imperceptibly the definition at the centre, so that the smallest images are actually not at the centre, but half or two-third the radius away.

But this enlargement of image means diffusion of light, so that the instrument is less sensitive and the stars recorded are less numerous at the margin of the field than at the best focus. In matters of counting this is very important, because it would produce a systematic deviation. Accordingly, the average amount of this deviation was determined and allowed for.

It was proposed to count a sufficient number of plates to determine the number of stars, zone by zone, in each of 8 zones of galactic latitude. Actually 30 plates were employed. They

are all in the northern hemisphere, but lie both north and south of the galactic equator. In each count it was proposed to determine the number of stars of each separate magnitude, and here arose one of the most crucial, as well as difficult, points. The magnitudes recorded ranged down to the 17th, or nearly to the 10-millionth of the brightness of a first-magnitude star. It was necessary to have the scale of magnitudes correct over this wide space, because any deviation would here again become systematic, and, altering the number of stars in each grade, would altogether distort the estimated total of the vast number of those beyond the reach of counting. You will understand how difficult it was to establish an absolute magnitude scale, when the limiting brightness of stars recorded varies upon each plate with the purity of sky and the elevation above the horizon. I will only allude to this difficulty and say that a scale was determined and was applied to each plate in a way that is practically beyond criticism. Standard specimens of the results were photographed within the eye-piece of the measuring microscope for comparison with the plates, and were used for the estimation of the magnitudes of all the stars. The counting then proceeded. Two computers were employed on the work, and it occupied them for two years. Success depended very much on skill. After the counting had proceeded for a few weeks, one of the earlier plates was recounted, and the number of stars detected was increased by 50 per cent. The whole of these early plates were, therefore, repeated, and, fortunately for finality, subsequent practice did not increase the numbers any more. Only the magnitudes from the 12th to the 17th were counted, as the material was already available for stars brighter than the 12th. These were found partly in some counts made at Harvard of stars from mag. 2 to 4·5, partly in some counts of Schwarzschild for mag. 5 to 7·5, but chiefly from the Greenwich Astrographic Catalogue from mag. 9 to 12·5, and a special Greenwich photometry with the Franklin-Adams 6-inch lens for mag. 6·5 to 9·0. The standard bases of all these, I need hardly say, were most carefully brought into adjustment. The results of this laborious

work are contained in a table [a diagram representing the table was shown on the screen]. B_m is the number of stars of magnitude m and brighter in each zone ; its logarithm is charted here in place of the number in order to make the diagram more compact. In this diagram is contained the net outcome of the counts, the distribution of stars, zone by zone, for every magnitude.

All the 8 curves, representing the 8 zones, are independent, and their similarity, which strikes us at once, is convincing proof of their reliability. They tell us that in every zone the *proportion* of stars of the various magnitudes is the same, as far as the eye can follow. If we look closely into the numbers it appears that there is perceptible a slight gradual increase of the proportion of the fainter stars as the galaxy is approached. Beyond this there is a gradual increase in density in the whole number of stars in the zones, so that at the equator of the galaxy it is 3 times as dense as at the poles. The progress is quite gradual over the whole sky. The galaxy does not produce a sudden rise in the numbers, and simply drops into the statistical register of the whole. Statistically, in spite of the striking contrasts you have seen, the "divine disorder" of the heavens, there are no other features than this, a gradual condensation amounting at the limit to three-fold towards the galaxy accompanied by a slight relative increase of the proportion of the fainter stars. That is, the statistical description of the distribution of the stars when attention is diverted from their random features

Passing now from the distribution in zones to the question of the total number of stars, the table on p. 76 exhibits the data before us :—

We see that, as we take in successively the 2nd, 3rd, down to the 17th mag., the proportionate increase of numbers, which is at first 3 per magnitude, falls progressively until at the 17th it is less than 2.

Beyond this it is almost wholly a matter of inference, but the progression is so steady that Mr. Chapman and Mr. Melotte have reduced it to a formula which, within the ascertained range,

admits of very little latitude, and shows that at about the 23rd or 24th magnitude we should have reached one half of the total, and that this total would lie between one and two thousand millions.

I say it is a matter of inference, because hardly any material was available to carry on the counts. Two plates, however, were forthcoming, one by that keen observer, Mr. D'Esterre, and one from Mount Wilson, and these when counted confirmed the forecast numbers in re-assuring fashion beyond the 20th magnitude — that is to say, down to stars 100 million times as faint as those of the 1st magnitude.

NUMBERS AND EQUIVALENT LIGHT OF THE STARS

Magnitude	Number	Equivalent Number of 1st mag. stars	Totals to mag. *m*
-1·6	Sirius	11	. .
-0·9	α Carinæ	6	. .
0·0	α Centauri	2	. .
0·0- 1·0	8	14	33
1·0- 2·0	27	17	50
2·0- 3·0	73	18	68
3·0- 4·0	189	19	87
4·0- 5·0	650	20	113
5·0- 6·0	2,200	35	148
6·0- 7·0	6,600	42	190
7·0- 8·0	22,550	50	240
8·0- 9·0	65,000	65	311
9·0-10·0	174,000	69	380
10·0-11·0	426,000	68	448
11·0-12·0	961,000	60	508
12·0-13·0	2,020,000	51	559
13·0-14·0	3,960,000	40	599
14·0-15·0	7,820,000	31	630
15·0-16·0	14,040,000	22	652
16·0-17·0	25,400,000	16	668
17·0-18·0	38,400,000	10	678
18·0-19·0	54,600,000	6	684
19·0-20·0	76,000,000	3	687
All stars fainter than 20·0		3	690

There is the result, between one and two thousand millions — I suppose somewhere about as many as the people on the globe. I confess to a feeling of a kind of relief in finding that the total is measurable and, comparatively speaking, moderate.

It may be well to add a few sentences in consideration of the

validity of the conclusion, which is, and must remain, an extrapolation beyond knowledge, a summation to infinity of a series not completely known.

We begin by admitting that we are dealing only with the sensible universe. There may be dark stars — in fact, we know that there are, because some of them have been detected in occulting the bright ones, as in the case of Algol. Naturally these are not counted. Nor do we reckon with the possible presence of absorbent matter in space, by which the magnitudes of all the stars seen would recede progressively, so that at the end of the series their light would be extinguished. Nor do we profess to unravel the details of globular clusters — we cannot do everything. For that matter, there is infinite detail in a drop of blood or an atom of gas. We take the stars as we find them. The relevant question is the possibility of a sudden break or a gradual change in the progression after the 20 terms that have been so carefully examined.

There would seem to be a certain kind of control in the total light received, but this proves illusory.

The total of starlight is a sensible amount, but it is very small. The table shown above is taken from a paper by Mr. Chapman; it shows that, for the ascertained magnitudes up to the 20th, the total light emitted is equivalent to 687 first-magnitude stars, which again has been put as equal to the hundredth part of full moonlight. If we include all the remaining stars, following the formula, the equivalent addition would be only 3 more first-magnitude stars. But this tells us very little; for if the progression were so altered that the total number were infinite, the total light could easily still be finite, owing to the reducing effect of higher magnitude.

We leave off our summation at a point where each additional magnitude is adding more stars than the last. If this went on, the number would be infinite. But, according to the formula, between the 23rd and 24th magnitudes there is a turning-point, after which each new magnitude adds less than before. The actual counts have been carried so near this turning-point

that there is no reasonable doubt of its existence. Given its existence, the number of stars is at least finite. That is a conclusion that I regard as open to very little doubt. At to the value of the sum, naturally we can be less positive. But all the indications of the earlier terms must be misleading if the margin between one and two thousand millions is not enough to cover the whole.

It is sometimes said that the British amateur astronomer, to whom in the past so much enterprising construction and so much sound and brilliant observation is due, has disappeared. No doubt the growth of organization continues to add strength proportionately to the great observatories. I imagine that the number of excellent amateurs to be found at any one time was never large. While we can produce men like Mr. George Higgs or Mr. Franklin-Adams, whom unhappily we have lately lost, or Mr. D'Esterre, who happily is with us, we need not be anxious. Professor Hale — himself, like Herschel and Gill, an amateur turned professional — once defined an amateur as a man who pursued astronomy because he could not help it. Mr. Franklin-Adams satisfied this test. Sir David Gill tells how, in 1903, he came to the Cape with the "incongrous double purpose" of curing the rheumatism and neuritis, which at that time almost incapacitated him, and of photographing the southern heavens. While the moon shone he retired to the sanatorium at Caledon, and at the end of the fortnight, against the best advice, he would emerge to sit up at nights and expose his plates. He has left the world a great gift, and happily has placed it in trust with the best possible hands, those of Greenwich Observatory, and it has been dealt with there as it deserves, with the unassuming mastery that so well becomes that great house, by the Astronomer Royal, Mr. Chapman, and Mr. Melotte, to the last of whom you owe the beautiful slides I have shown you this evening. We cannot dispense with discussion and with theory, and I would be the last to depreciate them, but I think you will feel we always owe a special debt of gratitude and affection to the indefatigable, the truth-loving race of observers.

MEETINGS OF THE SOCIETY

At Toronto

December 28, 1915.—A Regular Meeting of the Society was held in the Rooms, at 198 College St., at 8 p.m., Dr. Albert D. Watson in the chair.

The following nominations were made:—

Mr. Fred. S. Carrington, Washta, Iowa, proposed by Mr. D. E. Hadden and Mr. A. F. Hunter.

Miss E. P. Hayward, Mooresville, Missouri, proposed by Mr. A. F. Hunter and Mr. W. E. W. Jackson.

Mr. S. A. Kearle, Ross Bay, Victoria, B.C., proposed by Mr. J. R. Collins and Dr. Albert D. Watson.

Rev. A. C. Ridsdale, M.A., F.R.A.S., etc., Darjeeling, India, proposed by Dr. Albert D. Watson and Mr. J. R. Collins.

Election will take place at the next regular meeting.

The Librarian reported 66 publications received during the month.

Mr. Collins referred to the predictions for the next two weeks.

The change in the form of the Red Spot on Jupiter as noted by Mr. Denning, in *The Observatory*, was referred to by Mr. Collins.

Mr. Blake reported having seen the recent comet near δ Orionis.

The paper for the evening was given by Mr. James Young, on "The Humidity and Temperature of the Earth's Atmos-

phere." Explanation was first given of the terms used in hygrometry and the laws which govern, with examples. The effect of humidity on our physical condition was explained and the necessity shown for giving the humidity as well as temperature before one can judge as to the effect certain temperatures have on the body. By means of lantern slides different methods of measuring temperature and humidity were illustrated.

Some slides of Mount Wilson Solar Physics Observatory were shown by Mr. F. L. Blake.

W. E. W. JACKSON, *Rec.-Sec.*

AT VICTORIA

December 7, 1915.—The Annual Meeting of the Victoria Centre was held this evening, when the officers for the next year were elected and reports of work done during 1915 were presented. These will appear in the report of the Annual General Meeting of the Society which will be published in the next number of the JOURNAL.

Mr. A. W. McCurdy then gave a lecture on "The Planet of Romance."

"From the study of the planet Mercury it is found that it revolves around the sun in a little less than three months. Therefore, when starting from a point between the earth and sun, it has completed a revolution, the earth has moved forward on its orbit, and nearly thirty days more are required for it to catch up with the earth and again come to a point between it and the sun. Its greatest elongation from the sun occur at periods of nearly sixty days. When east of the sun it may be seen in the western sky towards the close of twilight, and when west of the sun it may be seen in the east in the morning at daybreak. Its greatest distance from the sun is 43,0000,000 miles; its least distance from the sun is 29,000,000 miles; its greatest distance from the earth is 135,000,000 miles, and its least distance from the earth is 51,000,000 miles.

"The most remarkable feature in the motion of Mercury is that when it is nearest to the sun it moves forward faster than it

ought to if under the attraction of the known bodies of the solar system only. What the cause of this accelerated motion may be has created a great deal of discussion among astronomers for a long time past. Are there other planets, at present unknown, between Mercury and the sun? Is it possible that such bodies, although numerous perhaps, are too small to be observed? Does even one unknown planet revolve inside the orbit of Mercury? The movements of Mercury certainly indicate an influence that might be accounted for by the presence of an inner planet. For convenience this mythical planet has received a name, the name of 'Vulcan.' It has also been called 'The Planet of Romance,' because it has given rise to so much conjecture, so much discussion.

"If it does really exist there should come a time when it would appear as a dark spot moving slowly across the face of the sun. It is true that owing to its nearness to the sun there would be very great difficulty in seeing a starlike point in that position, even in the very best of telescopes, and when recourse is had to the photographic plate, for the sun has been photographed nearly every day for many years, nothing indicating such an object has been discovered.

"There is another method, however, by which new planets in the vicinity of the sun may be detected, and that is to take observations during the total eclipse of the sun. If there are no clouds at such a time, when the sun vanishes, the stars spring forth. This would be an excellent time to look for this mysterious planet.

"During the total eclipse of the sun in 1878, Dr. Watson saw an object which he thought might be the long sought after Planet of Romance. In order to confirm his report, careful examinations have been made during all of the eclipses since that time, without, however, any such object being discovered, and it is now the general belief among astronomers that no planet has yet been found within the orbit of Mercury, and that the source of the attraction, not yet located, must be looked for in some other place.

"Is it possible, however, that after all, Vulcan—the Planet of Romance—may in fact exist within the orbit of Mercury as a glowing mass comparable in brilliancy to the sun? In this case, it might not be readily detected by any methods heretofore pursued.

"Now I am quite sure that one of the very first questions that we would be glad to have answered by the director of our new Victoria Observatory, as soon as possible afther the installation of the mammoth telescope here, will be: 'Have you been able to discover anything further regarding Vulcan, the Planet of Romance?'"

L. F. HOUGHTON, *Sec.*

NOTES FROM THE DOMINION OBSERVATORY

PHOTOMETRIC RESEARCH ON VARIABLE STARS WITH THE POLARIZING PHOTOMETER

In the *Astrophysical Journal*, Vol. XLII., p. 412-433, a summary is given of an investigation carried on at Princeton University Observatory on eclipsing variable stars. This article contains the important results obtained from this work, no detailed observations being given which would be of value to the investigator. The observations in a detailed form will appear in due time in a separate publication as a contribution from the University.

The four systems investigated are *TV*, *TW*, *TX* Cassiopeiæ and *T* Leonis Minoris. The great value of such research is the determination of stellar densities which have a direct bearing on our theories of stellar evolution. Of the four systems, three are of quite normal density, being, on the average, a little more than a tenth that of the sun; *TX* Cassiopeiæ, however, is unique in the respect that it is six one-thousandths the density of the sun, rather remarkable for a *B*-type star. *TX* Cassiopeiæ is also of special interest as the observations seem to confirm the theory of darkening toward the limb in stellar systems; the primary eclipse is continuous in its variation with no constant phase, while the secondary has a constant phase for a period of nearly five hours.

The well observed light curves demonstrate the value of repeated observations on eclipsing systems, such facts as eccentricity of orbit, ellipticity of stars, as well as reflection effects, are clearly brought out. In the case of *TW* Cassiopeiæ it was

possible from the observations to determine both components of the eccentricity, the quantity e and ω (Longitude of periastron). The light curve of *TX* Cassiopeiæ resembles, to a certain degree, a sine curve except for the secondary minimum, showing that the variation of the light of the star is continuous. The interpretation of the light curve is, that we have two ellipsoidal stars moving in an orbit whose plane is nearly coincident with the line of sight. From the observations we are able to determine the percentage of polar flattening of the stars.

The reflection effect is clearly brought out in the system *TV* Cassiopeiæ, the light curve shows that the brightness seems to increase gradually from primary to secondary eclipse. This is due to the fact that as the star approaches secondary eclipse more of the brighter side of the fainter star is turned toward the observer. In this particular system, it appears that the fainter star is twice as bright on one side as the other, caused by the radiation of the brighter star.

R. J. McDiarmid.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

December, 1915

Temperature.— The mean temperature of December was above average in all parts of the Dominion, excepting Southwestern Ontario, and the larger part of British Columbia. The widest positive departures occurred in Quebec and New Brunswick, in many parts of which Provinces the excess was between 6° and 9°, while in Alberta and Western Saskatchewan the excess was from 4° to 6°. The negative departures ranged between 1° and 3° in the Peninsula of Ontario, and were about the same in Northern British Columbia.

Depth of Snow and Precipitation.— At the close of the month the ground was covered with snow in nearly all parts of the Dominion. In British Columbia on the Mainland the depth ranged from one inch in the vicinity of Vancouver to two feet in the Northern Interior districts. There was little or no snow in some southern sections of Alberta, and throughout that Province the covering was quite light, but farther eastward the depth increased to ten or fourteen inches in southeastern Saskatchewan and Manitoba. In Ontario there was a depth of nearly two feet in some districts in the northern part of the province, but farther southward this gradually diminished to a few inches near Lakes Erie and Ontario. The Province of Quebec had a covering of from seven to twenty inches, while in the Maritime Provinces, there was a depth of only one to five inches. There were no pronounced differences from the normal precipitation in any of the Provinces.

Temperature for December, 1915

Station	December		Station	December	
	Highest	Lowest		Highest	Lowest
Yukon			Huntsville	35	10
Dawson	12	-30	Kenora		
British Columbia			Kinmount	35	-18
Atlin	37	- 7	Kingston	40	2
Agassiz	52	18	London	37	2
Barkerville	29	- 7	Lucknow	36	0
Kamloops	47	- 2	Markdale	37	1
New Westminster	49	19	North Gower	43	-10
Prince Rupert	51	22	Oshawa	39	1
Vancouver	51	33	Ottawa	36	8
Victoria	51	27	Paris	38	- 4
Western Provinces			Parry Sound	38	- 2
Battleford	40	-13	Peterboro'	39	-10
Calgary	51	- 9	Port Arthur	36	- 4
Edmonton	41	- 6	Port Burwell	40	7
Medicine Hat	53	- 3	Port Dover	39	9
Minnedosa	33	-22	Port Stanley	48	7
Moose Jaw	51	-18	Queensborough	37	15
Oakbank	33	-22	Ronville	35	-10
Portage la Prairie			Southampton	38	6
Prince Albert	36	-20	Sundridge		
Qu'Appelle	42	-16	Stonecliffe	32	11
Regina	38	-20	Stony Creek	49	5
Saskatoon	37	17	Toronto	41	10
Souris	35	-20	Uxbridge	37	7
Swift Current	54	8	Wallaceburg	46	9
Winnipeg	34	18	Welland	45	1
Ontario			White River	31	18
Agincourt	39	3	*Quebec*		
Aurora	35	- 7	Brome	47	10
Bancroft	35	19	Father Point	40	6
Barrie	37	- 2	Montreal	38	4
Beatrice	36	- 8	Quebec	38	- 3
Berlin	38	- 1	Sherbrooke	42	10
Bloomfield	40	2			
Brantford			*Maritime Provinces*		
Chapleau	49	18	Charlottetown	48	14
Chatham	43	12	Chatham	48	8
Clinton	38	0	Dalhousie	42	6
Collingwood	46	2	Fredericton	49	1
Cottam	48	0	Halifax	52	10
Georgetown	38	1	Moncton	49	6
Goderich	39	10	St. John	50	8
Gravenhurst	37	- 9	St. Stephen		
Grimsby	44	11	Sussex	50	3
Guelph	38	5	Syndey	46	20
Haliburton	36	13	Yarmouth	50	18

MAGNETIC OBSERVATIONS

During the month of December, 1915, the photographic record of the magnetic forces obtained at Agincourt indicate very little disturbance. The only magnetic storm of note occurred on the 6th and 7th. It began gradually early in the morning of the 6th and continued until about noon of the 7th. Pronounced maxima of Westerly Declination occurred on the 6th at $6^h\ 50^m$, and on the 7th at $2^h\ 50^m$, and pronounced minima on the 6th at $17^h\ 52^m$ and $22^h\ 27^m$. The Horizontal Curve shows much more rapid movements but generally of small magnitude, maxima were recorded on the 6th at 7^h, $17^h\ 38^m$, and $22^h\ 32^m$. The Vertical Force has two pronounced maxima on the 6th at $16^h\ 35^m$ and $17^h\ 34^m$ but for the most part is below normal.

Very few auroræ were recorded in Canada during December, and these were mostly on the 2nd, 7th, 11th and 25th. On the 2nd the magnetic forces were undisturbed and on the 11th and, 25th only lightly disturbed.

December, 1915		D. West	H	V	I
		° ′			° ′
	Mean of Month	6 30·2	·16008	·58575	74 42·4
	Maximum	6 50·0	·16081	·58703	74 48·8
	Date of Maximum	6	6	6	6
	Minimum	6 03·9	·15904	·58538	74 40·8
	Date of Minimum	6	6	6	6
	Monthly Range	0 46·1	·00177	·00165	0 08·0
Mean Daily Amplitude	From hourly readings	0 06·5	·00028	·00006	
	From Means of Extremes	0 11·9	·00048	·00018	

H and V are expressed in C. G. S. Units.

I is derived from H and V by the formula $H \tan I = V$.

W. E. W. J.

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1915		P. T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
			h m	h m	h m	h m	mm.	h m	
1533	Dec.	3		3 35·5	Air Currents				
1534	"	7	S 10 55·8	11 6·5		11 36·3	0·3	0 41·5	
1535	"	7		18 46·5		18 54·1	0·050	7·6	
1536	"	12	21 9·0? S 21 13·5	21 14·7	21 19·0	21 53·5?	1·7	0 44·5	A.C. going on.
1537	"	17	7 52·5? S-L.? 58·9	8 1·7	8 4·8	A.C.	0·3		
1538	"	18		19 8·0		19 14·9	0·2	0 6·9	
1539	"	28	23 51·4 S 23 56·6	0 4·0	0 4·4	A.C.	0·3		
1540	"	31	12 28·0? S 12 31·9	12 35·8	12 40·5	13 23·9?	1·8	0 55·9	2,380 km. [Eureka, California.
1541	"	31	23 13·3 S 23 21·6	23 24·7	23 26·0	0 12·1	0·3	0 58·8	16,775 km.

Period of Boom 18 seconds. Pillar deviation 1 mm. = 0″·50.

VICTORIA, B. C.

F. N. DENISON, SUPERINTENDENT.

No.	Date 1915	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1537	Dec. 3	3 31·4 S 3 34·9	3 38·3	3 40·3	3 53·2	0·5	0 20·8	2,040 km.
1538	" 7	11 08·7 S11 14·1	11 18·1	11 22·1	11 50·3	0·2	0 41·6	
1539	" 7	12 25.6?		12 27·0	12 50·3	0·2	0 24·7	
1540	" 12	21 32·9?	21 41·4	21 42·4	21 48·4	0·2	0 15·5	
1541	" 17	7 51·5?	7 59·5	8 03·0	8 11·0	0·2	0 19·5	
1542	" 18		19 28·0?		19 34·6	0·05		
1543	" 28	23 58·4	0 0·9	0 1·4	0 7·4	0·3	0 9·0	
1544	" 29		0 16·8	0 24·8	0 38·3	0·2	0 21·5	
1545	" 31	12 20·8 S12 22·3	12 25·3	12 26·3	13 25·3	1·4	1 04·5	830 km. Eureka California.
1546	" 31	23 16·0	23 16·5	23 21·5	23 49·5	0·4	0 33·5	

Period of Boom = 18 seconds. 1 mm. = 0″·54

WIECHERT VERTICAL.

Date 1915	P.T. Com.	L.W. Com.	Max.	End.	Amp.	Duration	Remarks
	h m s	h m s	h m s	h m s	μ	h m s	
Dec. 31	12 21 18·5 S 12 22 54·5	12 23 33·5	12 27 42·5	13 09 43·5	40	0 48 24·0	880 km. Eureka California.

Earthquake period at S = 8 seconds. At L. 17 seconds.

Dec. 31	23 05 34 S 23 07 38·5	23 15 06	23 10 34	?		1160 km.

Earthquake period at P = 2 seconds. At S 3 to 5 seconds.

J. Y.

COMET NEWS

In the last number of the JOURNAL appeared an account of the discovery of Taylor's comet and provisional parabolic elements of its orbit, which, however, was said to be uncertain.

In addition to the positions of the comet given in the last issue, the following have been published :—

G.M.T. 1915	R.A. h m s	Decl. s ′ ″	Observer	Place
Dec. 9·6817	5 21 3·30	+0 36 2·5	Wilson	Northfield, Minn.
12·7012	5 18 39·61	+1 30 23·9	Wilson	Northfield, Minn.
14·7501	5 18 0·49	+1 46 33·6	Burton	U.S. Naval Obs.
18·6478	5 15 37·15	+2 51 5·5	Burton	U.S. Naval Obs.
22·6633	5 13 13·34	+4 6 23·2	Burton	U.S. Naval Obs.

From observations of December 7, 13 and 18, Messrs. Neubauer and Jeffers, of the Students' Observatory, Berkeley, Cal., have computed the following elements and ephemeris, which show that the orbit is an ellipse with a short period, 5·30 years.

ELEMENTS

Time of perihelion passage	(T)	1916, January 27·91, G.M.T.
Perihelion minus node	(ω)	352° 54′
Longitude of node	(Ω)	114° 51′
Inclination	(i)	14° 30′
Perihelion distance	(q)	1·520
Eccentricity	(e)	0·5001
Period	(P)	5·30 years.

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT

G.M.T.		R.A.			Decl.		Light
1916		h	m	s	°	′	
January.	2·5	5	8	12	− 8	10·3	1·14
	4·5		7	39	8	59·6	
	6·5		7	14	9	50·2	
	8·5		6	59	10	41·5	1·13
	10·5		6	54	11	33·3	
	12·5		7	01	12	25·5	
	14·5		7	18	13	17·8	
	16·5		7	47	14	10·2	1·07
	18·5		8	28	15	02·4	
	20·5		9	22	15	54·2	
	22·5		10	27	16	45·6	
	24·5		11	44	17	36·4	0·98
	26·5		13	13	18	26·4	
	28·5		14	55	19	15·5	
	30·5		16	49	20	05·6	
February	1·5	5	18	55	20	50·7	0·88

Brightness December 13 = 1.

By marking the above positions on Map II., published in the HANDBOOK, the path of the comet amongst the stars will be found. It passes roughly northward into Taurus where it bends to the east.

Dr. R. K. Young has kindly supplied the accompanying diagram of the orbit in space and the note beneath it.

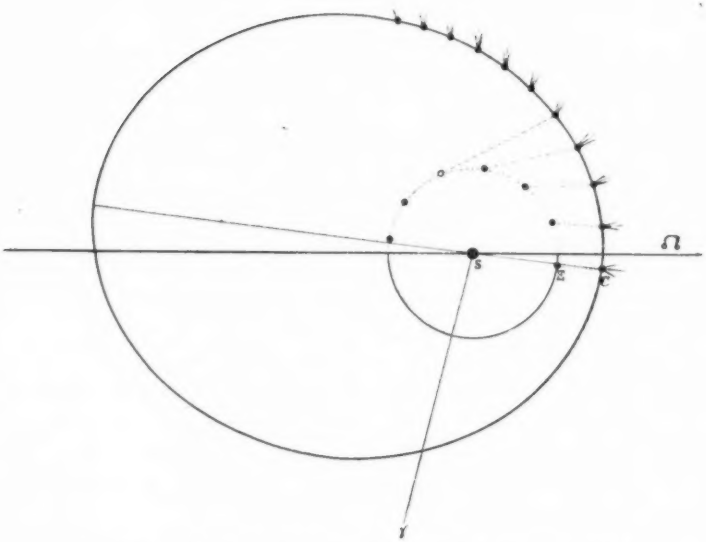

DIAGRAM OF THE ORBIT OF TAYLOR'S COMET, 1915

In the above diagram of the orbit of Taylor's Comet S represents the sun, E the position of the earth in its orbit on January 28 and C the position of the comet on the same date. The relative positions of the earth and comet for several intervals of thirty days from this epoch are joined by broken lines. The small inclination of the plane of motion of the comet to the ecliptic makes the comet move close to the signs of the zodiac. At the end of January it will be found in the constellation Taurus and it moves slowly through Gemini and Cancer, always being well above the equator and favorably placed for observation. At discovery it could be seen with a small telescope and theoretically its brightness will diminish very slowly. The elements as computed at the Students' Observatory, Berkeley, California, place the comet among the most frequent visitors we have. Other comets with short periods are, Encke's 3·30 years, Tempel's 5·28, Brorsen's 5·46, Swift's 5·68, Winnecke's 5·80.

C. A. CHANT.

ASTRONOMICAL NOTES

SUN-SPOTS AND PRESSURE.—A paper dealing with pressure data has been received from Dr. Gilbert S. Walker, who is engaged on a comprehensive statistical investigation in world meteorology with the object of laying the foundation of a secure system of seasonal weather forecasting. The data are treated as in the case of rainfall and temperature in preceding papers. For pressure the Indian area is characterised by negative correlation coefficients, whilst in the western hemisphere and boreal regions the opposite sign prevails. A general tendency is observable for the pressure coefficients to be opposite in sign to those for rainfall, indicating that their variations are dominated by a common cause, and temperature would seem to have little influence on either. Humidity, especially in the upper air, appears to control the relationship between sun-spot and temperature.—*Nature*, December 30, 1915.

PROBLEMS IN LATITUDE VARIATION.—During the years 1906-1911, the writer was in charge of the observations of latitude variation in the Tokyo Astronomical Observatory, under the auspices of the Geodetic Committee. This was in continuation of the series of observations made successfully by Professors H. Kimura and K. Hirayama. The instrument used was a zenith telescope of the usual form, made by Wanschaff in Berlin, No. 800, aperture $81^{mm.}$ and focal length $100^{cm.}$.

In order to determine the value of one turn of the micrometer screw, I made observations of polar stars at their greatest elongations every summer and winter. The total number of determinations during the period amounted to 58. When observing the polar stars in the eastern and western elongations, I found a remarkable fact, *viz.*, that the bubbles of the two levels attached to the zenith telescope moved gradually towards the south, both

in the eastern and the western positions of the telescope. Moreover, the magnitude of displacement was larger in winter than in summer, and it varied generally with the length of the observation.

With respect to the third cause, I may notice the fact that the horizontal pendulum observers in several parts of the world have revealed a remarkable unsteadiness of the ground. The most conspicuous of the regular movements has a period of one solar day, being due to the effect of the solar radiation on the earth's surface.

The notion that the level is not suited to the most delicate measurements is not novel. Already as early as in the year 1893, E. von Rebeur-Paschwitz insisted on the inadequacy of the spirit level to meet the disturbance in precise astronomical measurements from pulsatory or microseismic movements of the ground. Also G. H. Darwin is said to have declared to the same effect.

Although the motive of my idea is not strictly the same as that of these authorities, our resulting conceptions are convergent, and I am pleased to conclude my paper with the expectation that Darwin's prediction will be promptly actualized in order to meet the degree of accuracy required in up-to-date astronomical observation.—K. Sotome, *Journal College of Science*, Imperial University of Tokyo, Japan, November 30, 1915.

Absorption of Light in Space.—All researches on the structure of the stellar universe must take into account the probable and possible effects of the scattering or obstruction of light in its passage through interstellar space. It is recognized, for instance, that if the loss due to absorption, or scattering by the free molecules of matter in space totals as much as a millionth of one per cent of the visual light in a journey of a hundred million miles, then, assuming the effect proportional to the distance, every star 3500 light-years away would be observed about two magnitudes fainter than its true brightness. As a consequence any uncertainty in the coefficient of scattering, especially if it is large as cited above, is very serious in studies of the distance of the faint stars and particularly in considerations of the stellar densities in various parts of the galactic system. In fact, the hypothesis that light extinction is imperceptible is prerequisite to the conclusion that the stellar universe is finite in extent.

As the effect for blue light would be about double that for yellow, an obvious method of detecting and measuring selective absorption is through the study of the colors of faint and distant stars. By means of measures of color indices various investigators have found that the fainter stars are on the average redder than the brighter ones, and as the fainter stars are also on the average, the more distant, this excess of redness might be and often is accepted as an indication of space absorption. There are, however, other possible interpretations, including the effect of intrinsic luminosity on color and the possibility of the predominance of redder spectral types among the faint stars and more distant ones.

The most remarkable feature of the distribution of color class exhibited in the table is not the relative paucity of *a*'s and early *f*'s, nor the great range in color, but rather the highly significant fact that there are any negative color indices (*b*0 *b*9). Of the 495 stars more than 17 per cent. are of color class *b*, and of these one-fifth are bluer than represented by *b*5. Moreover, we find no excessively large color indices, and none unusually small. A comparison of these colors with those derived by Parkhurst for bright stars near the north pole shows an entirely analagous distribution among the various classes. There seems to be no reason to doubt the present result, and we are left with the conviction that, so far as present data go, normal negative color indices exist in the Hercules cluster in large numbers. From the remarks of the preceding paragraphs it is at once obvious that such a condition could not co-exist with measurable selective absorption of light in space.

It seems to be necessary to conclude that the selective extinction of light in space is entirely inappreciable, at least in the direction of the Hercules cluster. If we grant, on the basis of our data, a color excess of a tenth of a magnitude, and attribute it all to space absorption, the value of the coefficient can not then exceed + 0·0001 mag., an amount completely negligible in dealing with the ordinary isolated stars. In the light of this result we are probably justified in assuming that the non-selective absorption in space (obstruction) is also negligible.—HARLOW SHAPLEY, Mount Wilson Solar Observatory, *Proceedings National Academy of Science*, Washington, Vol. II., No. 1.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

ABOLISH THE FAHRENHEIT THERMOMETER

At irregular intervals, in the Anglo-Saxon countries, agitations gain sufficient momentum to bring on an open attack on our illogical and inconvenient systems of weights and measures. The latest example of this is to be seen in a bill introduced into the House of Representatives at Washington by Hon. Albert Johnston, the object of which is the abolition of the Fahrenheit thermometer. The bill contains three sections, as follows:

1. That the centigrade scale of temperature measurement shall be the standard in United States Government publications, the use of the Fahrenheit scale being discontinued at the option of heads of departments or other independent branches of the Government, either immediately upon the signing of this bill or at any time before January 1, 1920, except as provided in Section 3.

2. During the period of transition the Fahrenheit equivalent of centigrade degrees may be added in parentheses or as a footnote or in any other way, if in the opinion of heads of departments or independent officers it seems necessary.

3. The use of the Fahrenheit scale shall be permitted after January 1, 1920, in cases where it is required by State or municipal law, or in certificates of tests of instruments graduated in the Fahrenheit scale.

The present writer has long been in favor of simplifying our various arbitrary scales of measurement and he sincerely hopes the above bill will become the law in the great republic, and that the Government of Canada will pass a similar law. Of course, many of us would hardly be fully satisfied without the introduction of a decimal system of weights and measures, similar to

our coinage, but to do that would prove a very serious undertaking, while a change of thermometric scales could be made with comparative ease. In this proposal the Meteorological Service is deeply interested and to effect a reform in their established system might require a number of years, but I feel sure we would all quickly realise the benefit of the new scale.

In ordinary conversation when we wish to know the temperature we have in mind how much above or below the freezing point of water it is. Some writers speak of the number of *degrees of heat* or *degrees of frost* which the thermometer shows. But the reading on the Fahrenheit scale does not give this, except by subtracting or adding 32. In the winter time the readings are especially confusing. Now the centigrade scale would at once get rid of the confusion and we would very soon become accustomed to the lengths of the degrees in it.

NOTES ON AURORÆ

Mr. A. F. Hunter has drawn my attention to some interesting references to auroræ contained in an old volume entitled *Magnetical and Meteorological Observations at Lake Athabasca and Fort Simpson* by Capt. J. H. Lefroy, R.A., and at Fort Confidence, on Great Bear Lake, by Sir John Richardson, C.B., M.D., printed by order of H. M. Government (1855).

Captain (afterwards Sir Henry) Lefroy was in charge of the magnetic observatory at Toronto from 1841 to 1853. From September 23, 1843, to February 29, 1844, he was at Fort Chipewyan on Lake Athabasca (W. Long. $7^h\ 35^m\ 15 = 123°\ 49'$, N. Lat. $58°\ 43'$), after which he went to Fort Simpson (W. Long. $8^h\ 5^m\ 40^s = 121°\ 35'$, N. Lat. $61°\ 51'{\cdot}7$).

Sir John Richardson and Dr. Rae went in search of Sir John Franklin and were at Fort Confidence on Great Bear Lake (W. Long. $7^h\ 55^m\ 16^s = 118°\ 49'$, N. Lat. $66°\ 54'$) from October, 1848, to March, 1849.

DAYLIGHT AURORA

After the last-named date [May 6, 1844], as the brightness of the twilight made it very difficult to distinguish between light cirrus clouds and patches of aurora, it did not receive much attention, and was not again seen up to the close of the observations on the 25th May; it is, however, quite possible that close attention would distinguish aurora occasionally, by its motion, to a much later date, as it has been seen in early evening and morning twilight in lower latitude, and was undoubtedly seen at Toronto *in full daylight*, on the 29th September and 2nd October, 1851.—LEFROY, p. 141.

HEIGHT AND RELATION TO CLOUDS

For want of corresponding observations elsewhere, there are no data for computing the height of any of the displays, but I avail myself of stating, that the impression conveyed to the senses upon many occasions was altogether opposed to the idea of the seat of the display being so distant as it seems to be in lower latitudes. Those who have travelled in mountainous countries must have frequently seen the passage of clouds at a short distance above their heads, and remarked, that without the aid furnished by the neighboring peaks and rocks, there is most convincing proof of the nearness of the cloud afforded by the manner of its motion, the sensible unfolding of masses of vapor, by the distinctness with which every detail of its form is seen. Precisely of the same nature is the evidence frequently given to the senses in high northern latitude of the nearness of the aurora, and the universal belief of the fact among those who witness it perpetually, must be allowed to weigh somewhat in the same scale.—LEFROY, pp. 142-3.

Several times during the winter the auroral light was seen, both by myself and Mr. Rae, to pass in front of a mass of cloud. As we were both aware of the ease with which the eye may be deceived in such observations, we watched the displays of the phenomenon with sufficient scepticism to keep the attention on the alert, and no doubt remained in our minds of the reality of the fact. In former years I had seen similar occurrences more frequently, and even more manifestly. Thirty years previously I had entertained the belief that the aurora was connected with the formation of cloud, and other changes in the constitution of the atmosphere, and the nightly observations of this winter all tended to strengthen that opinion.—RICHARDSON, p. 329.

AUDIBILITY OF THE AURORA

With regard to the much disputed question of sound, neither the writer nor his assistant, Serjeant Henry, was ever positive of hearing any, but the latter thought he did so upon one or two occasions. The result of inquiries upon the subject was, that opinions were nearly equally divided among the educated residents in the country: a small majority of those the writer consulted, agreed that a sound sometimes accompanied the phenomenon, but among the uneducated and

native inhabitants, whose acuteness of sense is probably much superior to that of the other class, a belief in the sound is almost universal, and many individuals assured the writer they had heard it. Similar testimony has been borne very positively by the assistants at the Observatory at Toronto, upon one or two occasions of great display.—LEFROY, pp. 150-1

With respect to sounds of the aurora, the belief prevails in the Arctic regions that it is occasionally audible when very bright and active, at which times it is believed by the natives to be near the earth. Having witnessed the phenomenon some thousands of times without hearing it, I have become sceptical of its ever producing sounds audible on the surface of the earth. The sounds it is said to cause are likened by many to the rustling of silk; and I may observe that the curtain-like appearances and motions of the brightest auroræ are likely to be associated with the remembrance of such sounds, and also that the formation of minute icy spiculæ in very cold clear nights is accompanied by a crackling in the air. —RICHARDSON, p. 350.

THE CLIMATES OF CANADA

The Meteorological Office has recently issued a 90-page blue-book in quarto form, entitled *The Temperature and Precipitation of British Columbia*. The Director states that the continual demand for information regarding the climates of the provinces of Canada has exhausted the supply of pamphlets on the subject and he has arranged for the publication of a series of booklets dealing with such matters. They are under the editorship of Mr. A. J. Connor, the climatologist of the Service and the present one is a creditable production. The next one will deal with the Northwestern Provinces. The very extensive records of the Service, accumulated during the last seventy years, allow the preparation of comprehensive and authoritative monographs on our climates.

In Part I. of the present work, after a brief treatment of the province as a whole, a summary of the temperature and the precipitation is given for each of the natural divisions of the province. In Part II. the monthly, seasonal and annual means and extremes are given in a comprehensive series of tables.

One need not go very far in British Columbia to get a decided change in climate, as the following results, extracted

from the work, show. In this brief table are given the mean temperature and the precipitation of six chosen districts for the four seasons of the year, winter, spring, summer, fall. Winter includes the months December, January, February and the succeeding seasons each three months.

District	Mean Temperature				Precipitation			
	W.	Sp.	Su.	F.	W.	Sp.	Su.	F.
	°	°	°	°	in.	in.	in.	in.
Vancouver I., W. Coast	39	45	55	49	45	25	10	35
Vancouver I., E. Coast	38	48	61	49	18	9	4	15
Lower Fraser	37	48	61	49	21	12	6	21
Okanagan Valley	26	46	64	46	3	2¼	4	3
Windermere Lake	18	41	59	39	2¼	2½	5¼	3½
Atlin	7	31	51	34	3	1½	3	3½

POEM

The present number of the JOURNAL begins with a ringing patriotic poem by Dr. Albert D. Watson and I hope I shall be pardoned if I conclude it with two more stanzas by the same writer :

In the stars that gem the blue
Of the night,
In the storm and in the dew,
There is light ;
In the clouds that split with thunder,
In the soul athrill with wonder,
Over all and through and under,
There is love and light.

In the moon-gleam on the sea,
There is power,
In the spiral nebulæ,
In the flower ;
In the soul of true desire,
Present always to inspire
Like a gleam of pillared fire,
There is love and power

C. A. C.